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A STUDY OF RADIOACTIVE SELENIUM AND ARSENIC ISOTOPES

W. A. McMANUS

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A STUDY OF RADIOACTIVE SELENIUM AND ARSENIC ISOTOPES

Abstract of
A Thesis
Presented in Partial Fulfillment of the Requirements
for the Degree Master of Science

By

WILLIAM ANGELL McMANUS, B.S., B.C.E., M.C.E.
The Ohio State University
1952

Approved by:

Adviser

Thesis
M254
c.2

A STUDY OF RADIOACTIVE SELENIUM AND ARSENIC ISOTOPES

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B.S., U.S. Naval Academy, 1935
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(Approved by Marion L. Pool)

The bombardment of Germanium 76 with 16 Mev. alpha particles produces a negatron emission which was observed as a 4.4 Minute half-life, and enables the assignment with certainty of this activity to Selenium 79*. An indication of a weak 4 Minute activity was also observed when Selenium was bombarded with 17.2 Mev. gamma radiation.

The bombardment of Selenium with 17.2 Mev. gamma radiation produced the isomeric pair, Selenium 81* and Selenium 81, for which the half-lives were measured as 59.0 Minutes and 20.0 Minutes, respectively, and the ratio of (γ, n) production of the 59.0 Minute activity to the 20.0 Minute activity was computed as 0.64.

The possible presence of a 10 Minute activity resulting from the bombardment of Germanium 76 with alpha particles and Selenium with gamma radiation was noted.

A 52 Minute positron activity was not observed as a result of bombarding Germanium^{70} Oxide with 6 Mev. or 7.5 Mev. protons.

18046

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This type of research could not be accomplished without the direct and indirect assistance of many individuals. I wish, therefore, to acknowledge here their contributions to this undertaking and to express my appreciation to Professor Marion L. Pool for his patience and timely advice and guidance, to Mr Paul Weiler and Mr Donald Moore for cyclotron operation, and to Mrs Virginia Ridolfo for preparation of cyclotron target samples.

This research was conducted as part of the curriculum sponsored by the U.S. Naval Postgraduate School for officers in the Radiological Defense Engineering program.

INTRODUCTION

Many investigators have studied and reported on various isotopes in the Arsenic and Selenium region. A portion of an isotopic chart, given as Figure 1, shows the general status of this region. The availability of electromagnetically enriched stable isotopes from the Atomic Energy Commission, Oak Ridge, Tennessee, together with the increased energy available from the Ohio State University cyclotron due to recent modifications, made it appear that additional information might well be obtained to augment the knowledge of this region. Accordingly, investigations were undertaken concerned primarily with the radioactive isotopes Selenium 79, Selenium 81*, Selenium 81, Arsenic 79 and Arsenic 70.

For the information of other investigators in this field, there is given in Appendix I a summary of some results arising from bombardments of Bromine. These results were not correlated due to a lack of time to pursue this work.

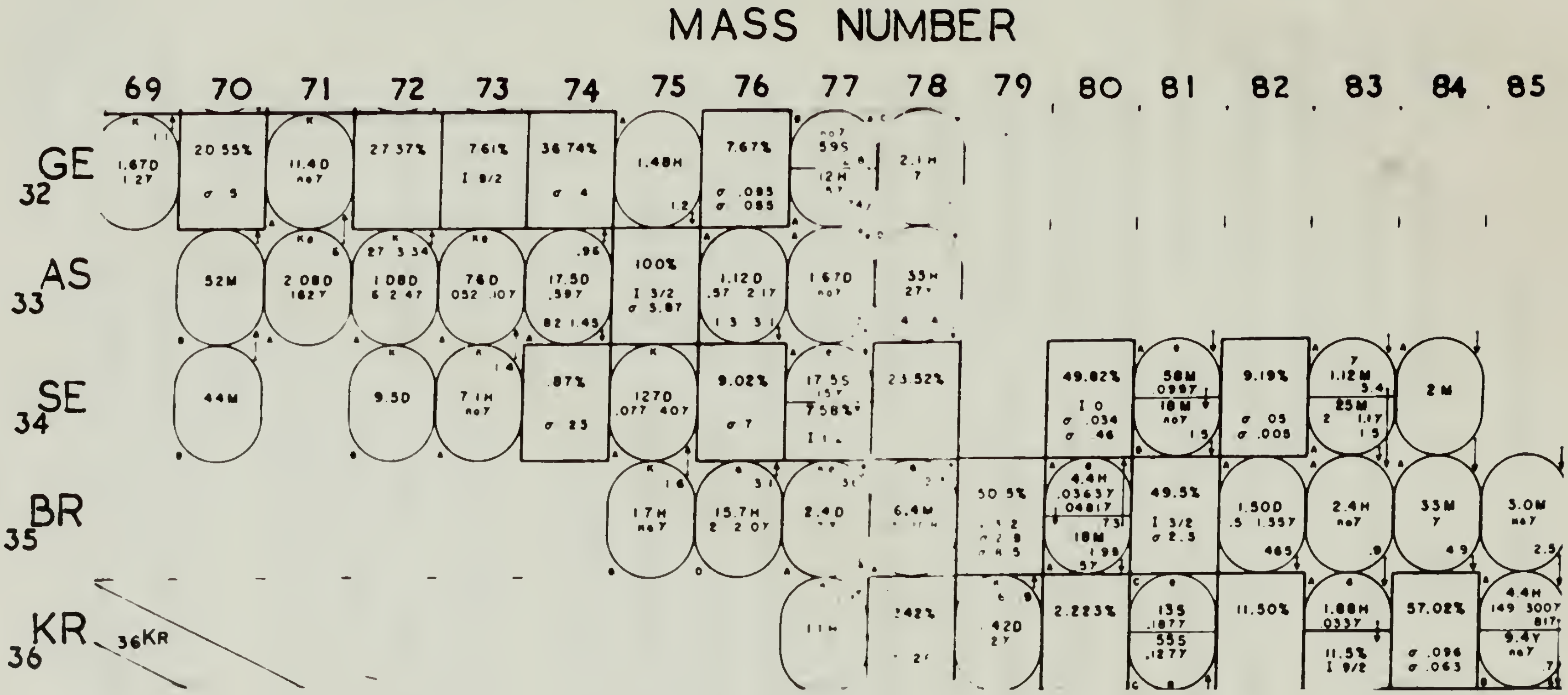
MASS NUMBER
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
$_{32}$GE
$_{33}$AS
$_{34}$SE
$_{35}$BR
$_{36}$KR
$_{36}$KR
1.67D
20.55%
11.4D
27.37%
7.61%
36.74%
1.48M
7.67%
59S
12M
2.1H
52M
2.08D
1.08D
76D
17.5D
100%
1.12D
1.67D
35M
44M
9.5D
7.1H
.87%
127D
9.02%
17.5S
7.58%
23.52%
49.82%
58M
18M
9.19%
1.12M
25M
2M
1.7M
15.7H
2.4D
6.4M
50.5%
4.4M
18M
49.5%
1.50D
2.4H
33M
3.0M
11M
.342%
.42D
2.223%
13S
55S
11.50%
1.88M
11.5%
57.02%
4.4H
9.4Y

Figure 1

EXPERIMENTAL PROCEDURE

Samples were bombarded in the Ohio State University 40" cyclotron which has a proton beam energy of about 7.4 Mev. at a frequency of 13.5 megacycles.

Activities were followed with G.M. end-window counting tubes in three types of counting arrangements:

a. Counting Rate Meter, type 1500A, with Esterline Angus Recorder. The counting tube, with a 5.8 mg/cm^2 window, was housed in a semi-closed counting chamber composed of 3" lead ingots.

b. "Positron Counter". This arrangement, by the use of a variable magnetic field, provided a means for counting separately the positively and negatively charged emissions. Either a Tracer Lab 64 Scaler or a Berkeley 2000 Decimal Scaler was used for counting. G.M. tubes with 2.50, 2.05, or 1.40 mg/cm^2 windows were used.

c. Counting Stand, with a 2" lead block semi-enclosed counting chamber. Either a Tracer Lab 64 Scaler or a Berkeley 2000 Decimal Scaler was used for counting. G.M. tubes with 2.05 or 1.83 mg/cm^2 end windows were used.

Energies were determined by observing activities through Aluminum or Lead absorbers, and determining visual range end points.

SELENIUM 79

Based on fission studies, Parker[1] gave the half-life of Selenium 79 as 6.5×10^4 years, decaying with negatron emission of 0.160 Mev. energy and no gamma radiation; Clendenin[2] calculated a lower limit of 7×10^6 years for the half-life provided the decay energy was greater than 30Mev.; and Katcoff[3] gave the negatron energy as about 0.160 Mev.

Geswind, Minden and Townes[4], while experimentally determining the masses of stable Selenium by spectrometer measurements of OCSe rotation lines, concluded that an upper limit of one part in 10, 000 might be set for the natural abundance of Selenium 79.

Flammersfeld and Ythier[5] reported a half-life of 3.9 minutes obtained from a Se(n,2n)Se reaction and a Se(n,γ)Se reaction, with negatron emission of 90 ± 10 Mev. energy. Flammersfeld and Herr[6] reported the 3.9 minute activity as being in the Selenium fraction as obtained from the Br(n,p)Se reaction using both slow and fast neutrons. Based on relative intensities of the 57 minute and 17 minute Selenium activities also produced, they assigned the 3.9 minute activity to Selenium 79*.

It is to be noted that the assignment of the 3.9 minute activity to Selenium 79* by Flammersfeld and Herr is still open to question. The Se(n,γ)Se reaction would allow assignment to Selenium 75, 77, 78, 79, 81, or 83. The Se(n,2n)Se reaction would allow Selenium 73, 75, 76, 77, 79 or 81.

Since the radiation observed was negatively charged, the assignment could be Selenium 77, 79 or 81. The Br(n,p)Se reaction allows final assignment to Selenium 79 or 81.

In order to determine the assignment as claimed, to Selenium 79, a series of bombardments of electromagnetically enriched $Ge^{76}O_2$ with alpha particles was undertaken. Naturally occuring Ge^{76} has a relative abundance of 7.67%. The enriched $Ge^{76}O_2$ has the following composition:

Ge Mass	% Abundance	Impurities
70	4.1	Cu less 0.004%
72	5.3	Fe less 0.004%
73	1.6	Mg less 0.004%
74	9.7	Si less 0.004%
76	79.3	

The following types of bombardments were undertaken:

a. One minute bombardment in an Aluminum target holder using an external probe. Counting, in the Counting Stand. The only activity observed was a 70 second half-life, presumably by a $N^{14}(\alpha,n)F^{17}$ reaction from Nitrogen entrapped in the sample.

b. Five minute bombardment in an Aluminum target holder. Counting, in the Counting Stand. A series of activities were found, the principal one being a 2.55 minute activity from the $Al^{27}(\alpha,n)P^{30}$ reaction which masked activities of a similar half-life.

c. Ten minute bombardments in a Copper target holder. The Positron Counter with a 1.4 mg/cm^2 window G.M. tube was used and the geometry was such as to give a semicircular air path of 4.4 cm from the sample to

the center-line of the G.M. tube. A series of four bombardments with enriched $Ge^{76}O_2$ and one bombardment with Hilger GeO_2 were made, from which a negatively charged emission of about a 4 minute half-life was observed. However, strong positron activities, from the $Cu^{65}(\alpha,n)Ga^{68}$ and $Cu^{63}(\alpha,n)Ga^{66}$ reactions, produced considerable scattering when no magnetic field was used, so that the electromagnetic radiation decay curve appeared to have a higher activity than that for the negatron emission plus electromagnetic radiation, as shown in Figure 3. Since this is clearly impossible, the electromagnetic radiation decay curve was corrected for scattering by the ratio indicated between the two residual curves.

The activity from one bombardment of enriched $Ge^{76}O_2$ was followed on the Counting Stand using a 1.83 mg/cm^2 window G.M. tube.

Results of the six bombardments gave activities as follows:

a. From Total Decay, Figure 2: 9.4 hours ($Cu^{63}(\alpha,n)Ga^{66}$), 1.13 hours ($Cu^{65}(\alpha,n)Ga^{68}$) and 9.7 minutes. The 9.4 and 1.13 hour activities considered together appeared as a 95 minute residual to the 9.7 minute activity. An aluminum absorption approximately checked the 4.1 Mev. energy of the 9.4 hour activity.

b. From Hilger Germanium: The negatron emission was very weak, but appeared to be about 5.5 minutes on

a 106 minute residual. The electromagnetic radiation was 9.2 minutes on a 108 minute residual. The positron activity was a 107 minute residual.

c. From the balance of the bombardments, of which Figure 3 is an example, the following activities were obtained:

Negatron	Electromagnetic	Positron
4.0 and 95 Min.	11 and 95 Min.	86 Min.
4.7 and 101 Min.	9.1 and 107 Min.	80 Min.
4.4 and 101 Min.	8.6 and 124 Min.	
4.4 and 106 Min.	9.0 and 97 Min.	106 Min.

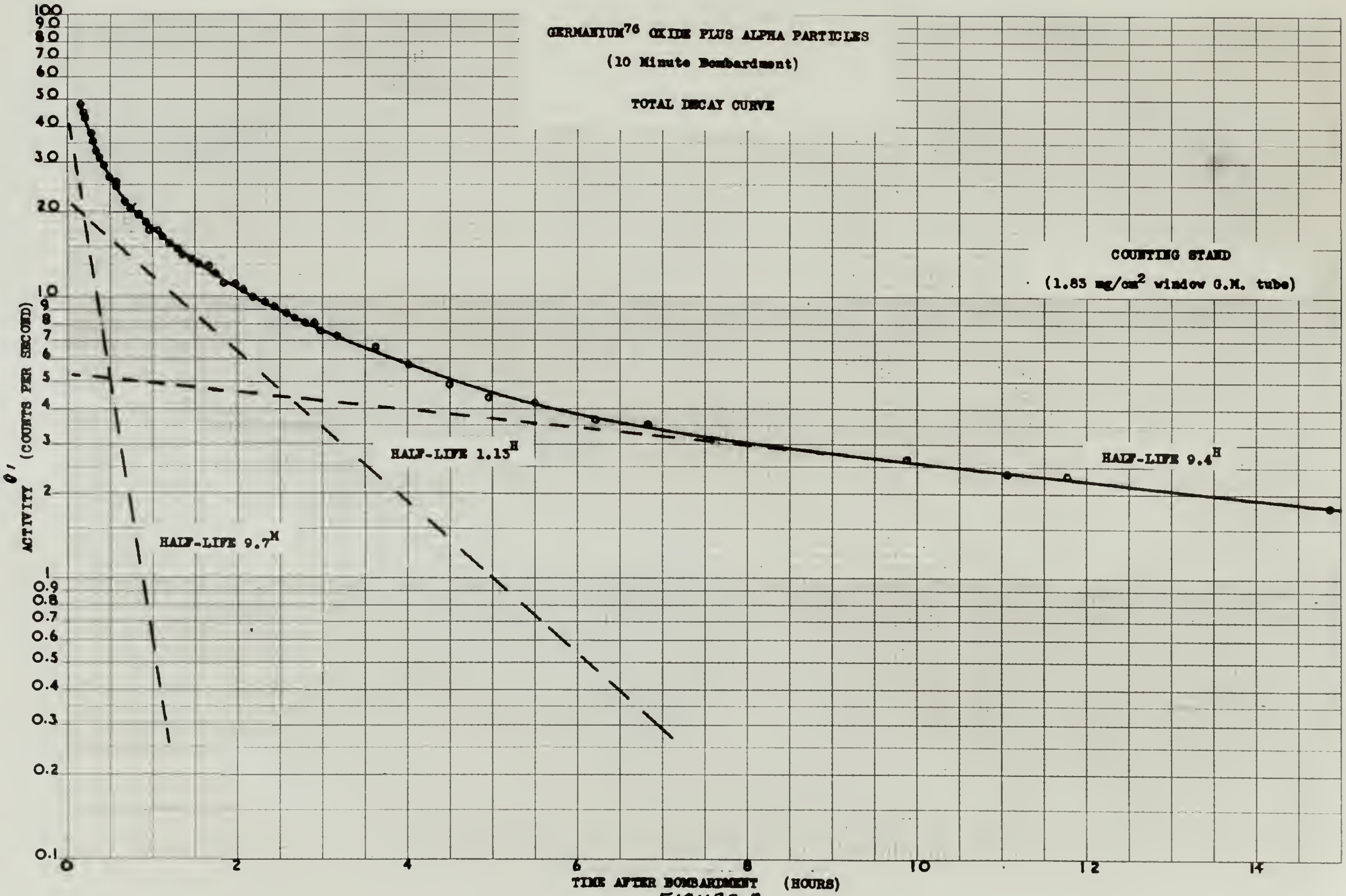
GERMANIUM76 OXIDE PLUS ALPHA PARTICLES
(10 Minute Bombardment)
TOTAL DECAY CURVE
COUNTING STAND
(1.83 mg/cm2 window G.M. tube)
HALF-LIFE 1.13H
HALF-LIFE 9.4H
HALF-LIFE 9.7M
ACTIVITY (COUNTS PER SECOND)
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2
4
6
8
10
12
14
TIME AFTER BOMBARDMENT (HOURS)

FIGURE 2

SELENIUM 81*, SELENIUM 81 and ARSENIC 79

An isomeric pair has long been known at the Selenium isotope of mass 79 or 81, reported with half-lives of 57 minutes[7,8,9] and 19 minutes[9]; 56.5 minutes and 13.6 minutes[10]; 59 minutes and 17 minutes[2]; and 18 minutes[5]. Langsdorf and Segre[9], using the Szilard-Chalmers chemical method for separation of nuclear isomers, showed that the long-lived activity decayed into the shorter activity. They also determined the energy of the longer activity as 98 Kev. gamma radiation and that of the shorter as negatron emission of 1.5 Mev. with no gamma radiation. Bergstrom and Thulin[11], using electromagnetic separation and a beta-spectrometer, determined the mass assignment as Selenium 81.

Bothe and Gentner[12], using the 17.2 Mev gamma radiation from Lithium for a Se(γ,n)Se reaction, reported the

$$\frac{\text{Yield of 17 Minute activity}}{\text{Yield of 57 Minute activity}} = \frac{3}{5} \text{ from one hour irradiation.}$$

Baldwin and Koch[13], using the x-radiation from a betatron to determine thresholds for (γ,n) reactions, gave a curve showing the rate of production of 57 minute Selenium to 17 minute Selenium as a function of x-ray peak energy. From this curve, the ratio at 17.2 Mev. is about 0.51. It is to be noted that while the data is given as a function of peak energy, the energy actually used was the integrated energy over the entire x-ray spectrum involved.

Butement[14], using 23 Mev. x-rays from a synchrotron to determine (γ,n) and (γ,p) reactions, irradiated Selenium for

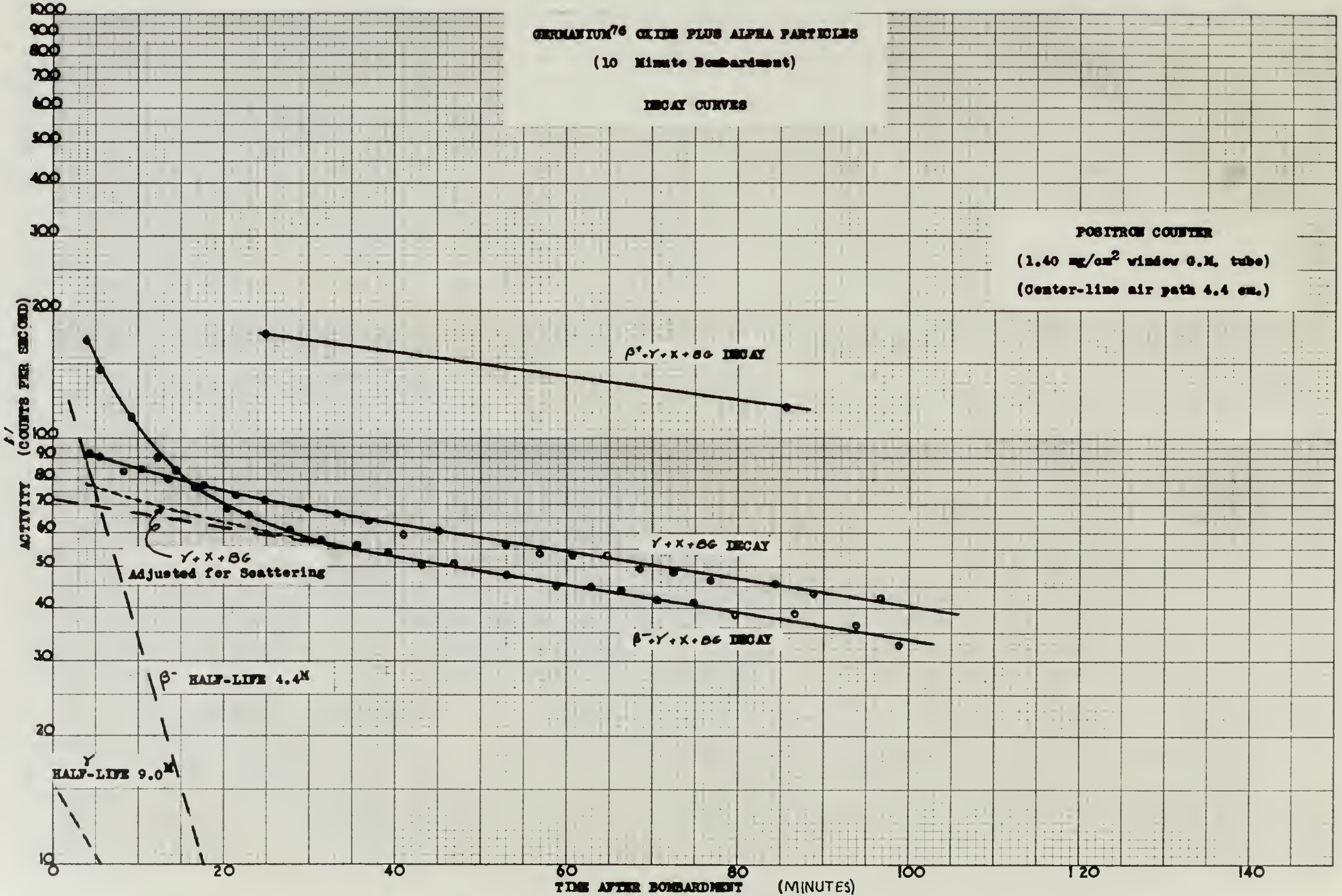
GERMANIUM^{76} OXIDE PLUS ALPHA PARTICLES
(10 Minute Bombardment)
DECAY CURVES
POSITRON COUNTER
(1.40 mg/cm^2 window G.M. tube)
(Center-line air path 4.4 cm.)
$\beta^+ + \gamma + x + BG$ DECAY
$\gamma + x + BG$ DECAY
$\beta^- + \gamma + x + BG$ DECAY
$\gamma + x + BG$
Adjusted for Scattering
β^- HALF-LIFE 4.4^M
γ HALF-LIFE 9.0^M
β^+
ACTIVITY (COUNTS PER SECOND)
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
0
20
40
60
80
100
120
140
TIME AFTER BOMBARDMENT (MINUTES)

FIGURE 3

SELENIUM 81*, SELENIUM 81 and ARSENIC 79

An isomeric pair has long been known at the Selenium isotope of mass 79 or 81, reported with half-lives of 57 minutes[7,8,9] and 19 minutes[9]; 56.5 minutes and 13.6 minutes[10]; 59 minutes and 17 minutes[2]; and 18 minutes[5]. Langsdorf and Segre[9], using the Szilard-Chalmers chemical method for separation of nuclear isomers, showed that the long-lived activity decayed into the shorter activity. They also determined the energy of the longer activity as 98 Kev. gamma radiation and that of the shorter as negatron emission of 1.5 Mev. with no gamma radiation. Bergstrom and Thulin[11], using electromagnetic separation and a beta-spectrometer, determined the mass assignment as Selenium 81.

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Butement[14], using 23 Mev. x-rays from a synchrotron to determine (γ,n) and (γ,p) reactions, irradiated Selenium for

one hour and found in the Arsenic fraction, after a 30 minute chemical separation, a 9 minute activity which he attributed to Arsenic 79 and with negatron decay into Selenium 79, whose half life would be either very short or very long. Vander Haack, DeVries and Aten[15], bombarded Selenium with 26.5 Mev. deuterons and with fast neutrons and in both cases observed a 10 minute activity with negatron emission of about 2.1 Mev. which they assigned to Arsenic 79.

In order to check for the production of Arsenic 79 and Selenium 79, Hilger powdered Selenium was irradiated for 30 minutes with 17.2 Mev. gamma radiation, produced by bombarding Lithium with protons. A copper target holder was used, and the Selenium sample was wrapped in a 0.004" Cadmium foil during bombardment to prevent activation by slow neutrons. The first bombardment was made using full power and the second bombardment with 2/3 power. From each bombardment two samples were prepared from the activated material. The activity of one sample was followed on the Counting Rate Meter and the other with the Positron Counter. All four samples showed strong 58.0 minute and 20.0 minute activities and a very weak residual of about 6 hour half-life. From the Positron Counter, these activities were determined to be negatron emission. Two samples indicated a possible 4 minute activity. One sample indicated a gamma emission of 10 minute half-life.

Scattering was evidenced when activities were taken

without the magnetic field as shown by electromagnetic radiation activities greater than positron plus electromagnetic activities. The latter activities were, therefore, used for the sample background.

Activities observed were as follows:

a. Counting Rate Meter (total decay):
   (1) 59.0 minutes and 20.0 minutes
   (2) 6.05 hours, 59.0 minutes and 20.0 minutes

b. (1) Negatrons of 4.8 hours, 59.0 minutes, 20.0 minutes and 4.0 minutes.
   (2) Negatrons of 6.05 hours, 59.0 minutes, and 20.0 minutes
   Gamma radiation of 10 minutes.

Figures 4 and 5 are typical decay curves.

In order to calculate the relative production rates of the isomeric pair, Selenium 81* and Selenium 81, two problems must be solved together, i.e., Parent-Daughter Production and Parent-Daughter Decay.

If N_1 and N_2 are the numbers of radioactive atoms of parent and daughter, respectively, present at any time , t_b, during bombardment; k_1 and k_2 are the respective rates of (γ,n) production of parent and daughter; t_d is the time of decay, starting from the end of bombardment; and N_1^0 and N_2^0 are the numbers of radioactive atoms of parent and daughter present at time $t_d = 0$ and time $t_b = T$, the following solution is given:

a. Parent-Daughter Production:

1. Parent Production: $\frac{dN_1}{dt_b} = k_1 - \lambda_1 N_1$

   Solution: $\lambda_1 N_1 = k_1 (1 - e^{-\lambda_1 t_b})$

2. Daughter Production: $\frac{dN_2}{dt_b} = k_2 + \lambda_1 N_1 - \lambda_2 N_2$

   Solution: $\lambda_2 N_2 = k_1 \left[1 - e^{-\lambda_2 t_b} + \frac{\lambda_2}{\lambda_2 - \lambda_1} (e^{-\lambda_2 t_b} - e^{-\lambda_1 t_b})\right] + k_2 (1 - e^{-\lambda_2 t_b})$

b. Parent-Daughter Decay:

1. Parent Decay: $\frac{dN_1}{dt_d} = -\lambda_1 N_1$

   Solution: $\lambda_1 N_1 = \lambda_1 N_1^\circ e^{-\lambda_1 t_d}$

2. Daughter Decay: $\frac{dN_2}{dt_d} = \lambda_1 N_1 - \lambda_2 N_2$

   Solution: $\lambda_2 N_2 = \frac{\lambda_1 N_1^\circ \lambda_2}{\lambda_2 - \lambda_1} e^{-\lambda_1 t_d} + \left(N_2^\circ \lambda_2 - \frac{\lambda_1 N_1^\circ \lambda_2}{\lambda_2 - \lambda_1}\right) e^{-\lambda_2 t_d}$

Since no 59 minute gamma radiation was observed, the total activity would be from the daughter only:

$$A = \lambda_2 N_2 = A_1^\circ e^{-\lambda_1 t_d} + A_2^\circ e^{-\lambda_2 t_d}$$

The observed activity = $C = C_1^\circ e^{-\lambda_1 t_d} + C_2^\circ e^{-\lambda_2 t_d}$

where: The initial observed activity with decay constant, λ_1,

is: $C_1^\circ = c A_1^\circ = c \frac{\lambda_1 N_1^\circ \lambda_2}{\lambda_2 - \lambda_1}$

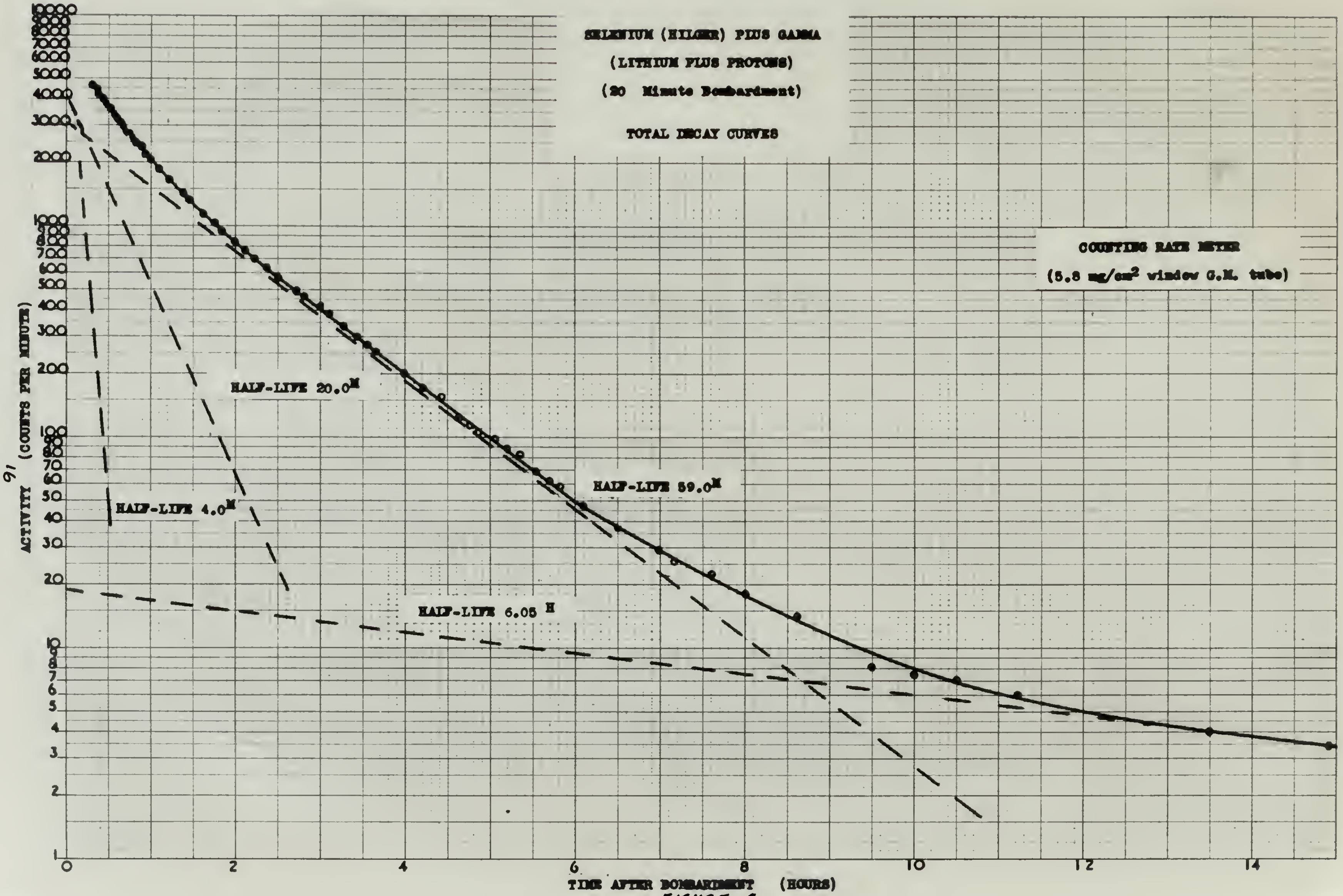
The initial observed activity with decay constant, λ_2,

is: $C_2^\circ = c A_2^\circ = c \left(N_2^\circ \lambda_2 - \frac{\lambda_1 N_1^\circ \lambda_2}{\lambda_2 - \lambda_1}\right)$

Then, from (a) and (b) above, at time t_b = T and t_d = 0:

$$\frac{k_2}{k_1} = \frac{C_2^\circ}{C_1^\circ} \cdot \frac{\lambda_2}{\lambda_2 - \lambda_1} \cdot \frac{(1 - e^{-\lambda_1 T})}{(1 - e^{-\lambda_2 T})} + \frac{\lambda_1}{\lambda_2 - \lambda_1}$$

The four samples gave ratios of production, k_1 to k_2 as 0.59, 0.57, 0.73 and 0.67 with an average of 0.64.



SELENIUM (HILGER) PLUS GAMMA

(LITHIUM PLUS PROTONS)

(20 Minute Bombardment)

TOTAL DECAY CURVES

COUNTING RATE METER

(5.8 mg/cm² window G.M. tube)

FIGURE 4

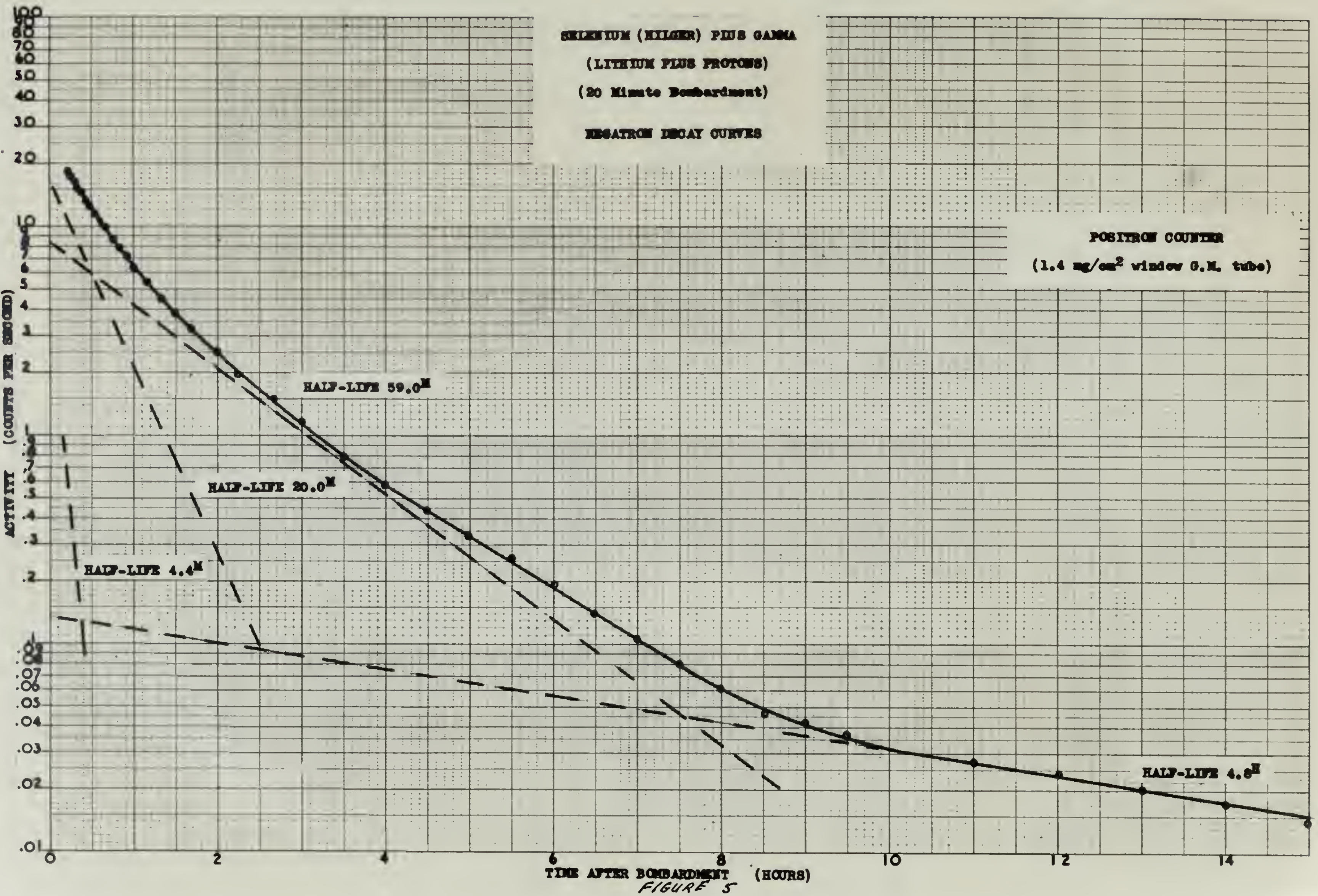

SELENIUM (HILGER) PLUS GAMMA
(LITHIUM PLUS PROTONS)
(20 Minute Bombardment)
NEGATRON DECAY CURVES
POSITRON COUNTER
(1.4 mg/cm² window G.M. tube)
HALF-LIFE 59.0M
HALF-LIFE 20.0M
HALF-LIFE 4.4M
HALF-LIFE 4.8H
ACTIVITY (COUNTS PER SECOND)
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
.9
.8
.7
.6
.5
.4
.3
.2
.09
.08
.07
.06
.05
.04
.03
.02
.01
0
2
4
6
8
10
12
14
TIME AFTER BOMBARDMENT (HOURS)

FIGURE 5

ARSENIC 70

Hopkins[16], bombarded Arsenic 75 with 190 Mev. deuterons and reported, among others, a radioactive chain : Selenium 70 decaying with positron emission of 44 minute half-life to Arsenic 70 which decays with positron emission of 52 minute half-life to stable Germanium 70.

In an attempt to check the 52 minute activity from Arsenic 70, two proton bombardments, each of one hour, were made using Germanium 70 Oxide electromagnetically enriched from 20.55% to 86.1%, as follows:

Germanium Mass	% Abundance	Impurities
70	86.1	Al 0.15%
72	6.2	Cu 0.03%
73	1.1	Fe 0.04%
74	4.4	Mg 0.02%
76	1.2	Ag 0.04%
		Si 0.08%

Protons of about 8 Mev. were used for one run, and the activity was followed for 6 days on the Positron Counter. The following activities were observed:

a. Negatron of 27 hours half-life, probably 1.1 day Arsenic 76 from a $Ge^{76}(p,n)As^{76}$ reaction.

b. Electromagnetic radiations of 27 hour, 3.5 hour and about 1 hour half-lives.

c. Positrons of 65 hour and 2.05 hour half-lives. The 2.05 hour activity was probably 1.87 hour Flourine produced by protons on Oxygen. No activity of a shorter half-life was observed.

Protons of about 7.5 Mev. were used for one bombardment. The activity of the sample was followed with the Counting Rate Meter, using a 5.8 mg/cm^2 G.M. tube, for 31 days, and with the Positron Counter, using a 1.4 mg/cm^2 G.M. tube, for 7 days. 8 aluminum and 8 lead absorptions were taken on the Counting Stand, using a 1.83 mg/cm^2 G.M. tube, during the first three days. The following results were obtained:

a. Total Decay, see Figure 6,:

17.5 Day half-life, C_o= 350 cpm. Probably Arsenic 74.

2.33 Day half-life, C_o= 1920 cpm. Probably Arsenic 71.

1 Day half-life, C_o= 12,300 cpm. Probably either Arsenic 72 or Arsenic 76.

1.87 Hour half-life, C_o= 4130 cpm. Probably Flourine 18 from the action of protons on Oxygen.

43 Minute half-life, C_o= 20,000 cpm. This could be the 38 minute Zinc 63 activity produced from the Copper impurity.

b. From the Positron Counter:

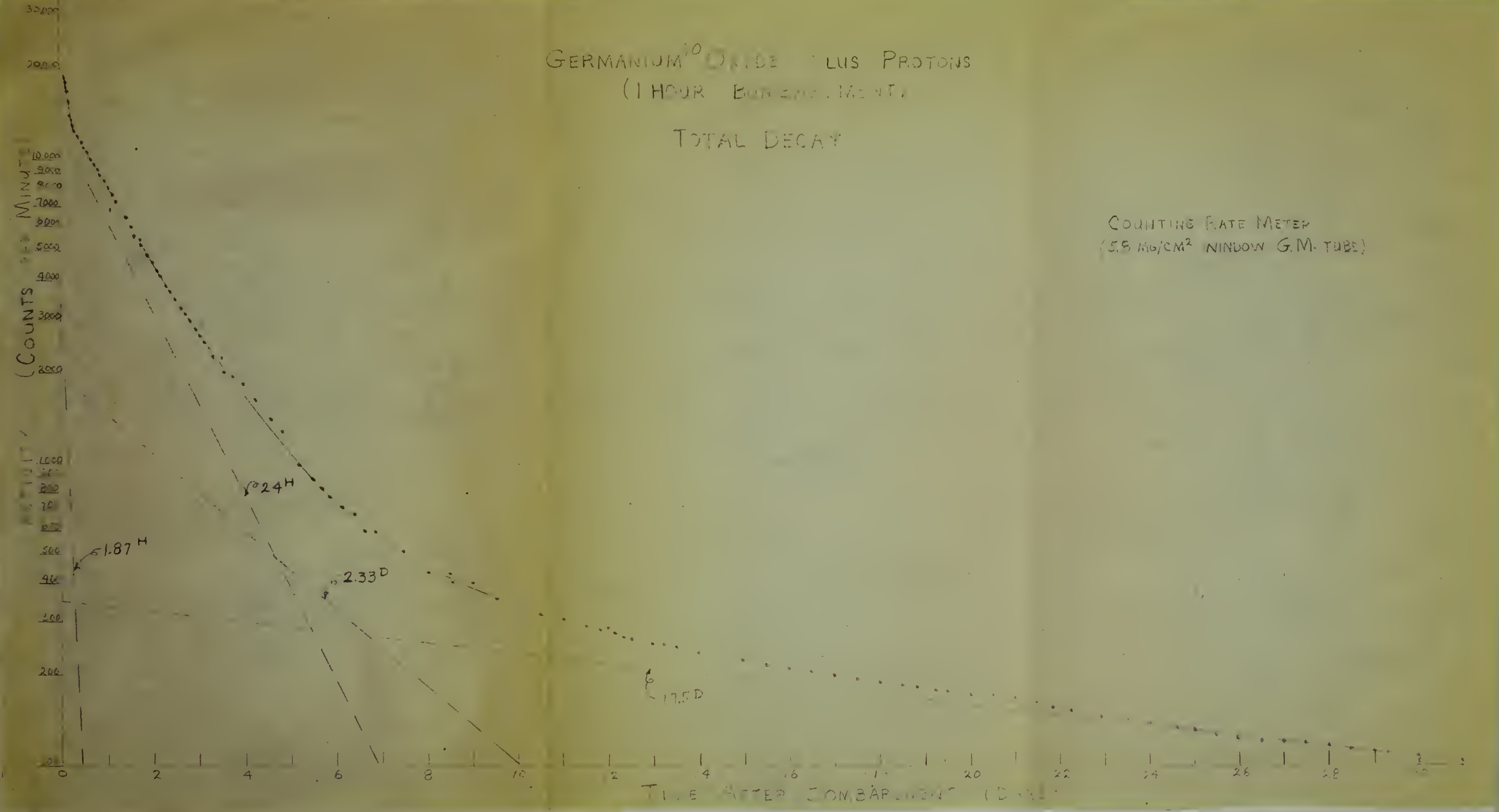
Negatrons with an indicated 30 Hour half-life going into a longer period after 5 days. Probably 1.12 Day Arsenic 76 and 17.5 Day Arsenic 74.

Electromagnetic Radiations of about 2 Hours, 1 Day, 2 Days and a longer period half-lives.

Positrons with half-lives of 47 Minutes, 2.89 Hours, 29 Hours, and a longer period. The activity

from the sample was very strong, and a gross Positron activity of 1600 counts per second was recorded at 42 minutes after bombardment ended. The G.M. tube used was indicated by the manufacturer to have a resolving time of 200 microseconds. Assuming uniformly spaced counts, it was computed that 32% of the counts would be lost at the 1600 cps rate and 20% at the 1000 cps rate. In view of these losses, the positron activities are probably due to Zinc 63 (38 Min), Flourine 18 (1.87 Hours), Arsenic 71 (2.08 Days) and longer Arsenic periods.

c. Absorptions. The first Aluminum absorption was taken at 1 hour after the end of bombardment and the last at 72 hours. All showed approximately the same end point of 2.7 Mev. and the same half-thickness of 4985 mg/cm^2 which would indicate electromagnetic radiation of about 0.15 Mev. The first lead absorption was taken at one hour after the end of bombardment and the last at 81 hours. All showed approximately the same half-thickness of 6.4 gm/cm^2 which would indicate electromagnetic radiation of about 0.69 Mev.


GERMANIUM^{70} OXIDE PLUS PROTONS
(1 HOUR BOMBARDMENT)
TOTAL DECAY
COUNTING RATE METER
(5.5 MG/CM^2 WINDOW G.M. TUBE)
ACTIVITY (COUNTS PER MINUTE)
30,000
20,000
10,000
9000
8000
7000
6000
5000
4000
3000
2000
1000
800
700
600
500
400
300
200
100
24^H
1.87^H
2.33^D
17.5^D
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
TIME AFTER BOMBARDMENT (DAYS)

CONCLUSIONS

The bombardment of Germanium 76 with 16 Mev. alpha particles produces a negatron emission, observed as a 4.4 Minute half-life, which, in view of the previous work by Flammersfeld and Ythier[5] and Flammersfeld and Herr[6], enables the assignment with certainty of this activity to Selenium 79*.

The bombardment of Selenium with 17.2 Mev. gamma radiation produced an indication of a weak 4 Minute negatron activity which is most probably Selenium 79*, produced by the $Se^{80}(\gamma,n)Se^{79}$ reaction.

The bombardment of Germanium 76 with alpha particles produced in total decay an observed 9.7 Minute activity, over a 70 minute period, but no observed shorter-lived activity. On the Positron Counter, no negatron activity longer than the 4 Minute period was observed; however, an electromagnetic radiation of about 10 Minute half-life was observed from all alpha bombardments of Germanium 76 and from one bombardment of Selenium with gamma radiation. Since, however, this 10 Minute activity was observed for only about 4 half-life periods, it could possibly be a scattering phenomenon. The presence of a 10 Minute activity is possible, but not conclusive, from these results.

The bombardment of Selenium with 17.2 Mev. gamma radiation produced the isomeric pair, Selenium 81* and Selenium

81, for which the half-lives were measured as 59.0 Minutes and 20.0 Minutes, respectively, and the ratio of (γ, n) production of the 59.0 Minute activity to the 20.0 Minute activity was computed as 0.64, in good agreement with the 0.51 observed by Baldwin and Koch[13]. The shorter period previously reported in the literature for Selenium 81 might have been due to the presence of small amounts of 4 Minute Selenium 79*.

A 52 Minute positron activity was not observed as a result of bombarding Germanium^{70} Oxide with 6 Mev. or 7.5 Mev. protons. It is concluded, therefore, either that the production of this activity was too small to be observed, or that the threshold for the reaction is above the energy available from the cyclotron.

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APPENDIX I

KRYPTON ACTIVITY

Sodium Bromide was bombarded with protons for 40 minutes in an Aluminum target holder, after which the sample was dissolved with water in a closed evacuated system and the gas (Krypton) released, was collected in an evacuated flask and then brought to atmospheric pressure. The activity in the flask was counted through a 0.00035" Aluminum foil window with the Counting Rate Meter. One activity only, of 2.87 Hour half-life was observed as shown in Figure 7. The energy, by Aluminum absorption end point was greater than 0.6 Mev.

BROMINE ACTIVITIES

Silver Bromide^{81}, electromagnetically enriched to 96.81% Bromine 81, was placed in a silver target holder and bombarded for 1 minute, 2 minutes and 1 hour. The activities were followed with the Positron Counter and with the Counting Rate Meter. Aluminum absorptions were taken on the Counting Stand. On the Counting Rate Meter from a 1 hour bombardment, activities with half-lives as follows were observed: 9.0 Days, 6.7 Hours (probably Cadmium 107), 34 Hours (probably Krypton 79), and 66 Minutes. On the Positron Counter from a 1 minute bombardment activities with half-lives of 7.5 Hours, 19 Minutes and 3 Minutes were observed for positrons and about 4 minutes for negatrons.

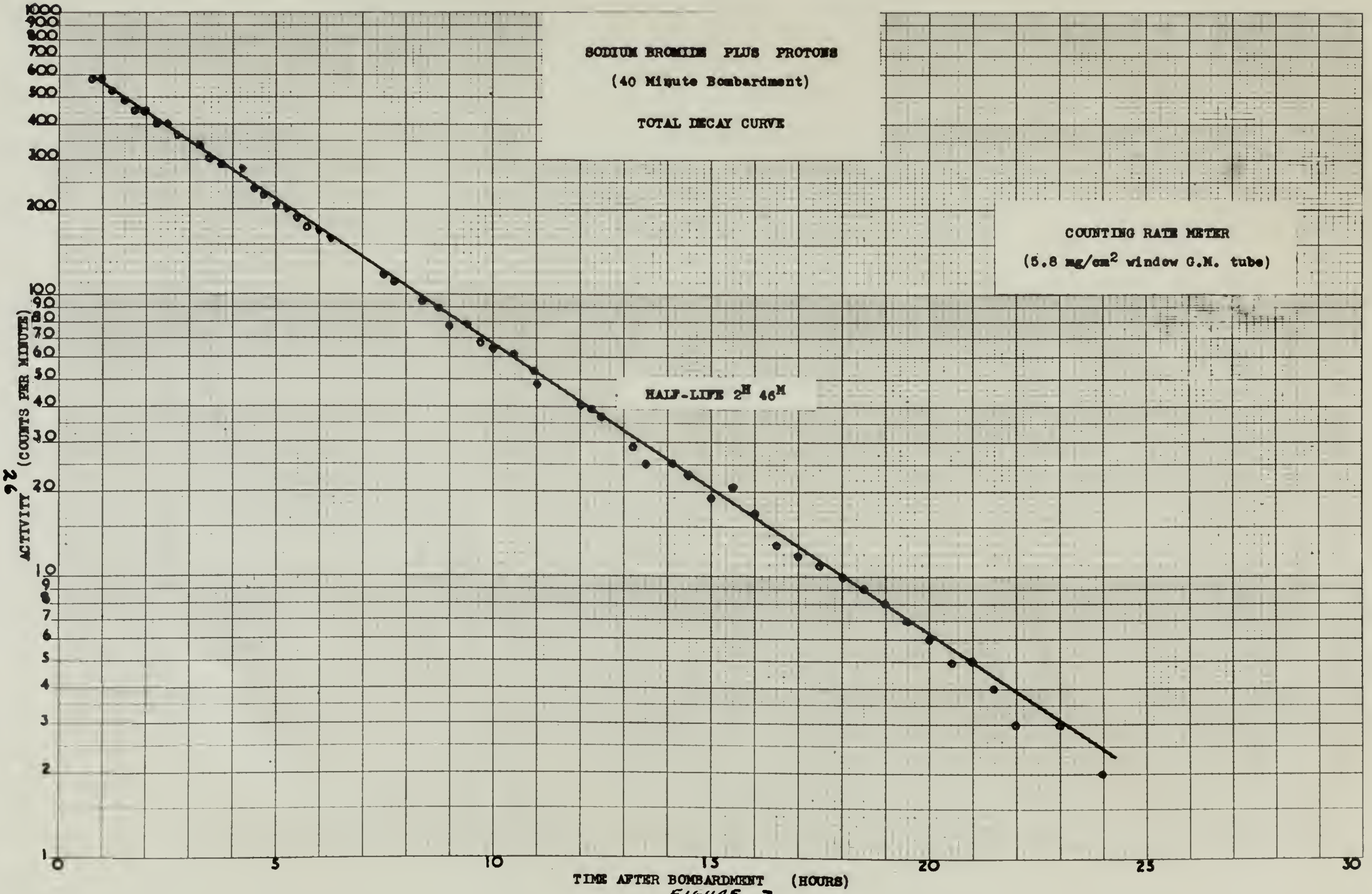
SODIUM BROMIDE PLUS PROTONS
(40 Minute Bombardment)
TOTAL DECAY CURVE
COUNTING RATE METER
(5.8 mg/cm² window G.M. tube)
HALF-LIFE 2ᴴ 46ᴹ
ACTIVITY (COUNTS PER MINUTE)
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
0
5
10
15
20
25
30
TIME AFTER BOMBARDMENT (HOURS)

FIGURE 7

OCT 2 BINDERY

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c.2 A study of radioactive selenium and arsenic isotopes.
OCT 2 BINDERY

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M2
c.

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M254 McManus
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